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(54) Three-dimensional optical memory system.

(57) A three-dimensional optical memory system is disclosed which utilizes at least two layers of electron trapping media having different sensitivities to visible light coated on a substrate to store data in the form of light energy. Data is written onto the substrate, which may be in the form of a disk, which is contained in a light-tight contamination-free environment similar to a Winchester hard disk drive system, using at least two visible light laser beams having different wavelengths. Data is read from the disk using an infrared light laser beam. The at least two different data streams are separately detected. The system may be used as part of an optical disk drive system which is designed to fit within a standard mini or 5-1/4 inch disk drive form factor for personal computers.

FIG. 1

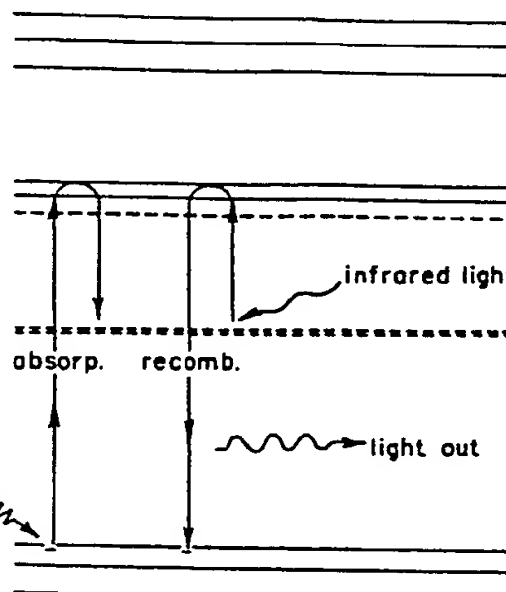
CONDUCTION BAND
(almost empty)

COMMUNICATION BAND E

TRAPPING LEVEL T

VALENCE BAND G
(ground state, full)

charging light



THREE-DIMENSIONAL OPTICAL MEMORY SYSTEM

This application is a continuation-in-part of United States Patent Application Serial No. 225,846, filed July 29, 1988 and entitled "Optical Disk Drive System."

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BACKGROUND OF THE INVENTION

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Cross Reference to Related Applications

The assignee herein is also the assignee of United States Patent Application Serial No. 870,877, filed June 5, 1986 and entitled "Optical Memory Method and System," and United States Patent Application Serial No. 184,263, filed April 21, 1988 and entitled "Thin Film Photoluminescent Articles and Method of Making Same." The disclosures of both of those applications are incorporated by reference herein.

The present invention relates generally to mass storage devices for data storage. More particularly, the present invention relates to a method of and apparatus for mass data or information storage utilizing purely photoelectronic processes for writing, reading, and erasing stored data.

Optical storage devices presently known generally permit two to three orders of magnitude more data to be stored per disk than with magnetic methods and apparatus. Because of the potential for much greater storage of data and also because of the enormous projected market for such optical memories, active development of optical storage devices is currently occurring in several different directions. Such activities are directed towards read-only, write-once-read many times (WORM) and erasable optical memory systems. While read-only and WORM optical memories are already available, erasable optical memory systems have encountered much greater developmental difficulties than read-only WORM systems because the qualities of the storage media required present problems of much greater technical complexity.

Read-only optical memory devices for use as computer peripherals, such as CD-ROMs, became commercially available with the advent of the digital audio compact disk. Current disk data storage capacity for such units is 200-600 megabytes. Such disks are factory fabricated using a molding press and metalizing operations and are suitable for low cost distribution of large fixed database information.

WORM devices allow the user to encode his own data on the disk, however only once. Data bits are stored at physical locations by irreversibly "burning" the medium with a laser. Such permanent encoding can be read back indefinitely, thus making WORM technology suitable for archival storage of large quantities of information, including digitized images, where random access to a large database is desirable.

It is the third category of optical disk storage devices, namely erasable storage devices, that is believed to embody the greatest utility for mass storage purposes. Such devices will be competitive with present magnetic tape and disk mass storage, and will have a major impact on computer technology in the years ahead. At present, the three most active approaches now being pursued for erasable optical storage involve magneto-optical material systems, dye polymers, and techniques that produce crystal structure or phase transformation in the storage medium at the spot being written to. All of these approaches require heat which usually changes the physical or chemical structure of the materials in performing the write or erase function. Thus, the time to write data to such systems is dependent upon a certain "dwell" time during which the spot to which data is being written must be heated or otherwise physically transformed.

Another drawback with such approaches is that media performance is highly sensitive to impurities, impurity diffusion, oxidation, and other imperfections that propagate into defects and that only show up after multiple switching cycles or at times later than the manufacturing and testing of the devices. Of the three approaches discussed above, progress has been greatest with magneto-optic materials. Laboratory results in this area have reported millions of write/erase cycles. See, for example, H-P. D. Shieh Ph.D. Thesis, Carnegie-Mellon University, Pittsburgh, Pennsylvania (1987).

In order to utilize erasable optical media for mass storage, the optical media must be fast enough to be marked at high data rates using low power lasers. The media must also maintain almost error-free data at acceptable computer industry standards for at least ten years, for example, no more than one uncorrectable error in 10^{12} bits. Thus, finding the right physical phenomenon to serve as the basis for erasability in a high-speed, high-resolution optical storage medium for use with an optical disk storage system or other optical storage system has been very difficult. Most of the effort in the optical disk area over the past ten years, as

described above, has gone into the use of magneto-optic materials. However, the commercial realization of erasable magneto-optical storage has not yet been achieved, nor are there yet any guarantees that it ever will be. Unfortunately, the performance of the other approaches discussed above generally is not comparable.

5 In order to overcome the problems of the prior art, and provide a basis for a workable optical disk storage system, a new approach to the optical storage materials problem which satisfies the optical media requirements of density, speed and long cycle life has been developed. This development utilizes the phenomenon of electron trapping in a class of new materials which comprise an alkaline earth crystal typically doped with rare earth elements. Thin crystalline films of such materials are formed on various
10 substrates, such as glass, polished sapphire or alumina, or other optical quality substrates, in order to provide the disk storage medium.

Since the trapping phenomenon is a purely electronic process, read/write/erase operations can be performed very fast. In addition, the physical trapping phenomenon suggests that media life may be practically limitless. Also, the effect of electron trapping yields a linear response characteristic, which
15 provides an analog dimension to the storage capability. Thus, for example, the potential disk storage capacity of a single 5-1/4 inch disk could be extended to several gigabytes. Obviously, the density of stored information is extremely high.

The materials to be used as the media for the optical disk storage system described herein are the subject of United States Patent Application Serial No. 184,263, filed April 21, 1988 which is a continuation-in-part of United States patent Application Serial Nos. 870,877 and 870,809, both filed June 5, 1986. Other
20 materials useful as the storage media herein are disclosed in copending United States Patent Application Serial Nos. 034,332 and 034,334 both filed in April 3, 1987; United States Patent Application Serial No. 147,215, filed January 22, 1988; and United States Patent Application Serial No. 078,829, filed July 28, 1987. The assignee herein is the assignee in each of those applications. The disclosure of each of those
25 applications is incorporated by reference herein.

The material described, for example, in Serial No. 184,263, demonstrates an extremely linear relationship between the intensity of the write input light and the read output light resulting from a fixed-intensity read command. Thus, this capability demonstrates a large noise margin for binary storage, as well as an increased information storage density when employed as an analog or multilevel digital memory medium.
30 Multilevel refers to the fact that by writing with a plurality of intensities of the same laser beam, the linearity of the resulting emissions upon being impinged by a read laser beam is such that information can be stored and recognized at various "levels" of intensity, for example, at .2, .4, .6, .8 and 1 intensity.

This particular media is in the form of a thin film and can be "charged" and "discharged" with light by exciting ground state electrons to an elevated energy level. Specifically, upon illumination by visible light,
35 electrons are raised to high energy trapping states, where they can remain indefinitely. When later illuminated by infrared light, the electrons are released from the traps, emitting a new visible light. Thus, with such materials, digital or analog data is stored and retrieved by using low energy lasers to trap and read the electrons at a particular location.

Such solid state photonic materials have electrons having bistable equilibrium states; one with electrons
40 in a ground state, and the other in which electrons are "trapped" in a well-defined, specific, elevated energy state. Electrons are raised to the higher energy state by the absorption of visible light photons, thus filling available trap sites. An electron in the elevated energy state can be released from its trap site by inputting sufficient energy to the electron to permit it to escape from the well. When that occurs, the electron falls back to its ground state and emits a corresponding visible photon. The number of electrons in the elevated
45 energy state is proportional to the visible light intensity used for recording. Thus, as a result of such characteristics, such materials can, in effect, "store" light energy.

The purely photo-electronic mechanisms involved in such electron trapping materials obviate the need for any thermal excursions and, therefore, the number of electrons trapped in the material is inherently linear. Since localized resolution of the "write" step depends only on the performance of the addressing
50 optics, an optical writing spot diameter of one micron will allow at least 550 megabytes of storage on a 130 mm or 5-1/4" disk coated with a single thin film material as disclosed herein. Multiple layers of thin film materials provide for a like multiple of data storage. For example, two layers of thin film materials will at least double the data storage capacity to 1.1 gigabytes. with the use of encoding techniques such as MFM, modified MFM, or record length limiting (RLL), which techniques are commonly used with magnetic disk
55 recording, the storage capacity can be increased by up to a factor of 3 over the use of FM or frequency modulation coding. The rise and fall times associated with optical read and write pulses are in the nanosecond range. Thus, the read and write data transfer rates have been found to be at least 200 megabits per second for optical disk drive media utilizing electron trapping materials.

Rotating disk memory systems require directions for the retrieval of the stored information. One set of those directions informs the drive mechanism where the requested information is or will be stored. The other set provides alignment for the read/write mechanism during processing. The alignment parameters include focusing, speed, tracks, and mark locations. The writing of information is dependent upon the media used such as write once, magneto-optic, dye polymer, or phase change, but in all cases, involves a change in the reflection parameters in the spot written to. The read method is based on detecting such reflectivity changes at the surface of the disk.

The common method presently used for tracking with reflective surface optical disks, such as the compact disc, is to rely on a grouped track as the principal mode of aligning and focusing the read/write head in the middle of the track. The speed information is either contained in the repetitive pattern of marks or in a depth modulation of the group.

Yet another tracking method presently utilized is known as the "Sampled Servo" system. That system relies on changes in the reflection of spots on the disk surface. The spots are located in a manner which provides information about the track location, the speed of the disk and the adequacy of focusing.

The erasable optical disk memory systems disclosed herein, which rely upon a thin film of electron trapping material as the media, do not rely on reflection for readout. Rather, the emission of the media under infrared stimulation can be utilized to retrieve pre-written tracking information from the disk.

However, even with the advances made by the assignee herein set forth above, the two-dimensional memory system disclosed in United States Patent Application Serial No. 225,846 has certain limitations. With the advent and continued development of parallel processing computers, very fast response memory systems having extremely high density storage capabilities are needed.

While there is much interest and development in two-dimensional erasable optical memories, such an approach will eventually run into an optical resolution limit. That is, a focused beam of light, even a laser, can only be made so small, somewhat less than one micron in diameter. Due to that limitation, only a limited number of bits stored per unit area can be achieved. In order to overcome that physical shortcoming, the present invention utilizes a three-dimensional optical memory storage system, that is, a plurality of at least two layers of different electron trapping materials, each of which responds to light of different wavelengths, in order to greatly increase the storage capacity of, for example, an optical disk memory system equipped with a disk prepared in such a manner.

As an alternative to utilizing "stacked" layers of different characteristic electron trapping materials, a buffered stack of two-dimensional storage planes could also be utilized. Electron trapping material characteristics can be controlled separately, together, or in a defined sequence. Both electron trapping media layers and optical layers can be utilized.

SUMMARY AND OBJECTS OF THE INVENTION

In view of the foregoing, it should be apparent that there exists a need in the art for a method of and apparatus for operating and constructing a three-dimensional erasable optical disk memory system in which electron trapping material used as the storage media permits writing, reading, and erasing essentially an unlimited number of times in which at least two layers of electron trapping material, each having a sensitivity to a different writing beam wavelength, are utilized. It is, therefore, a primary object of this invention to provide a method of and apparatus for operating and constructing a three-dimensional erasable optical disk drive system which is characterized by a plurality of electron trapping media layers such that the write, read, and erase functions can be accomplished with high density, speed and without serious degradation over a large number of erased functions.

More particularly, it is an object of this invention to provide a three-dimensional erasable optical disk memory system for information storage which is capable of storing orders of magnitude more data per disk than inductive magnetic media systems or than even two-dimensional erasable optical disk memory systems.

Still more particularly, it is an object of this invention to provide a three-dimensional erasable optical disk drive memory system in which data is stored as light energy and which is not dependent upon the reflective properties of the disk for effecting storage or readout of stored information.

It is another object of this invention to provide a three-dimensional erasable optical disk memory system in which data is written to and read from the disk in a parallel manner.

It is yet another object of this invention to provide a three dimensional erasable optical disk memory system in which one or more write laser beams centered about different wavelengths of visible light are

used to simultaneously write data to one or more electron trapping media layers, respectively.

It is still a further object of the present invention to provide a three-dimensional erasable optical disk drive memory system in which the data stored in each of the electron trapping media layers is released simultaneously by the use of a single infrared reading light beam.

5 It is still a further object of this invention to provide a three-dimensional erasable optical disk drive memory system in which the data released from each of the plurality of electron trapping media layers is centered about a predetermined wavelength of light and therefore can be readily separated.

It is also another object of this invention to provide a three-dimensional erasable optical disk drive memory system in which data may be stored as light energy in either digital or analog form.

10 Briefly described, these and other objects of the invention are accomplished in accordance with its apparatus aspects by providing a disk containing at least two coatings of thin film electron trapping materials, each having a different light sensitivity characteristic, which is rotated in a manner similar to that of magnetic hard disk drives, also known as Winchester disk drives. Data is read onto the disk in the form of a like number of write lasers operating at a like number of different wavelengths of visible light, preferably 15 with wavelengths peaking between 450 and 600 nanometers. A read laser is utilized to irradiate the disk with near infrared radiation having a wavelength with peaks between 700 and 1,450 nanometers, but preferably at about 1,000 nanometers. When stimulated by the near infrared read radiation, any stored bits (representing, for example, a binary one) will cause a predetermined radiation emission characteristic that peaks in a predetermined light band, for example, at about 620 nanometers (orange) and 495 nanometers 20 (blue). Such detected emissions correspond to a binary one recorded at those points. The absence of such radiation emission characteristic corresponds to a binary zero recorded at those points.

The optical disk memory storage system of the present invention also includes an optical processing unit for transmitting both the read and the plurality of write laser beams to the read/write head, as well as various detector electronics and positioning electronics for positioning the head over the disk. Data output 25 and data input is handled by a standard computer interface.

The disk is constructed of a substrate onto which the at least two layers of electron trapping material are deposited as thin film media. The two or more thin film media layers are separated by the use of deposited optical coatings. As such, information can be written, read and erased by multi-color optical signals. The time required for performing any of those functions is on the order of about five nanoseconds. 30 Using such electron trapping media materials, a practically unlimited number of interrogations can be made before the information is no longer accessible.

The electron trapping media layers are deposited utilizing such different deposition techniques as electron-gun evaporation and sputtering. The electron trapping layers may be placed directly on top of each other or may be separated by passive optical layers. Although only two electron trapping media layers are 35 shown and described in the embodiments herein, it is both possible and desirable to form a memory system having "n" electron trapping media layers, as long as each layer is sensitive to a different wavelength of visible light for writing purposes and produces a separable wavelengths of output light in response to an infrared reading laser beam.

40 With these and other objects, advantages and features of the invention that may become hereinafter apparent, the nature of the invention may be more clearly understood by reference to the following detailed description of the invention, the appended claims and to the several drawings attached herein.

BRIEF DESCRIPTION OF THE DRAWINGS

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Figure 1 is a diagram showing the principles of operation of the thin film storage media applied to the surface of the disk used with the present invention;

50 Figure 2 is a graph showing the trap-filling efficiency of a particular electron trapping film suitable for use with the present invention as a function of the wavelength of the exciting energy;

Figure 3 is a graph showing the relative infrared sensitivity for the read and erase functions for the same particular electron trapping material as Figure 2;

Figure 4 is a graph showing the wavelengths of emission from the disk upon infrared illumination of the disk for the same particular electron trapping material shown in Figures 2 and 3;

55 Figure 5 is a graph of the relative luminescence or read output as a function of write energy for the same particular electron trapping material as shown in Figures 2-4;

Figure 6 is a pictorial diagram of the structure of an optical disk for use with the present erasable optical disk memory system;

Figure 7 is a schematic block diagram of the electronics and optics necessary for reading, writing, and erasing data onto and from the disk;

Figure 8 is a pictorial partially cutaway drawing of an optical disk storage system which may be used with the present invention;

5 Figure 9 is a schematic block diagram of the position servo tracking and velocity servo tracking circuitry for use with the optical disk drive memory system of the present invention; and

Figure 10 is a schematic block diagram of the optical processing unit and actuator arm assembly for use with the optical disk drive memory system of the present invention.

10 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now in detail to the drawings wherein like parts are designated by like reference numerals throughout, there is illustrated in Figure 1 an explanation of the basis of the operation of the class of optical storage media electron trapping materials used with the erasable optical disk drive memory system of the present invention. As illustrated in Figure 1, the wide bandgap host material includes selected impurities which are associated with energy levels E and T. The narrow E band is designated as the communication band since electron interaction is allowed there. At level T, which is referred to as the trapping level, the trapping sites are non-communicating because they are of such concentration and separation as not to allow electron interaction.

As indicated in Figure 1, visible radiation, or charging light, excites carriers so that they can fill the trapping sites. The trap depth in this group of II-VI phosphors is about 1.2 electron volts, sufficiently above the thermal energy range such that electrons cannot be dislodged by thermal agitation. By controlling the trap density, the tunneling interchange at trapping level T may be cut off. Under such conditions, the trapped electrons cannot communicate with each other, and the possibility of recombination is thus eliminated.

When the charging radiation terminates and the electron trapping material is in its energized state, the traps are filled, the communication band E is empty, and recombination from the trapping level T to the valence band G is nonexistent. As a consequence, the electrons in the trapping level T will remain or be "stored" there for many years.

If the charged electron trapping material is then exposed to infrared or near infrared light, sufficient energy equal to the difference between the energy of an electron in the communication band E minus the energy of an electron at the trapping level T is provided which serves to move electrons from the trapping level T to the communication band E. While in the communication band E, the electrons may interact and then return to the ground state or valence band G. However, as the electrons return from the communication band E to the valence band G, a photon of energy E minus G is emitted. By the selection of an appropriate doping rare earth element, the wavelengths of light given off by the photon emitted when an electron falls from the communication band E down to the valence band G can be predetermined. The sensing of the occurrence of such an emission serves to indicate whether a particular point being addressed on the disk surface contains a bit (signifying a 1) or no bit (signifying a 0), or vice versa.

In contrast to the physical changes which occur by the use of a writing laser beam in known approaches to erasable (and non-erasable) optical storage systems, the writing and erasing of a spot on the surface of electron trapping materials requires only a change in the energy state of the electrons at that spot. Since no heating is involved, latent, defect induced read, write, and erasable forms of degradation do not occur. Consequently, the number of switching cycles in the electron trapping material is virtually unlimited, exceeding 10 million write/erase cycles with no observed change in the thin film.

The filling of the traps at trapping level T requires that a threshold energy be exceeded. A characteristic curve for one of the preferred electron trapping materials for use as one storage media with the present invention is shown in Figure 2. That preferred material is disclosed in pending United States Patent Application Serial No. 078,829, filed July 28, 1987. As shown in Figure 2, the threshold energy level which must be exceeded in order to fill the trapping level T begins at wavelengths of visible light shorter than 600 nanometers.

After the traps contained in the trapping level T are filled, impingement of near infrared radiation can cause electrons to be released. A graph showing the relative infrared sensitivity versus the peaks of the infrared radiation is shown in Figure 3. In all instances, the graphs shown in Figures 2-5 are for the same material described in connection with Figure 2. As shown in Figure 3, for the material discussed herein for use with the preferred embodiment, the most efficient rate of release occurs at wavelengths having peaks of just under 1 micron, or at about 1,000 nanometers.

As shown in Figure 4, when one of the thin phosphor films disclosed herein for use in the preferred embodiment is stimulated by infrared radiation having peaks whose wavelengths are shown in Figure 3, that phosphor film displays an emission characteristic that peaks in the orange light band, at about 620 nanometers. It should be noted, however, that Figures 2-5 are only representative and that peak
 5 wavelengths can be altered by changing the rare earth element dopants to produce other emission characteristics. In addition, the spectral widths of the responses can also be altered within certain limits.

The number of electrons trapped in the higher energy state at trapping level T is proportional to the amount of writing energy incident on the surface of the thin film electron trapping material. As shown in Figure 5, saturation is reached, for that thin film material, at a level of about 5 millijoules per square
 10 centimeter. At lower flux levels, linearity is observed through orders of magnitude. In addition, the readout emission is also linear with respect to the intensity of the write beam. This linearity characteristic of the electron trapping material allows such material, using the optical disk drive system disclosed herein, to record and read back analog signals, such as video or analog data transactions, using amplitude modulation, which is not possible with other optical disk drive systems.

If the traps contained in the trapping level T are physically separated by more than a tunneling distance, they do not communicate with each other and self-discharge is eliminated. This condition corresponds to a highest density of excited electrons on the order of about 10^{20} per cubic centimeter. Each time an infrared signal is applied to the charged electron trapping film characterized in Figures 2-5, emission of orange light occurs. Of course, with each photon emitted, the number of electrons remaining in
 20 traps in the trapping level T is reduced. Depending on the sensitivity of the detector which, in this case for this material is at 620 nanometers, many readings can be made before the traps are depleted. For the examples given herein, complete erasure of a bit storage spot 1 micrometer in diameter requires approximately 1 picojoule of infrared energy. Of course, depletion can be avoided by reading at lower levels of intensity. Periodic refreshing or immediate rewriting of data are both possible.

As briefly described above, the ability of electron trapping materials to "store" energy received in the form of light and to later release that energy upon interrogation by another light beam, comprises the means of digital switching used by the storage media of the present invention. Data points on the storage media surfaces that have electrons trapped in the elevated state can be interpreted as "on" or a binary one, while those with no electrons in the elevated state are interpreted as "off" or binary zero. Conversely,
 30 changed data points can be interpreted as "zeros" and unchanged data points as "ones". It is also possible to "charge" the entire disk with visible light and to write data using the infrared read beam. In that case, the ones or zeros would be stored on the disk at points which have been discharged and vice-versa.

Since at each such spot there are sufficient electrons that can switch energy states, the present invention optically determines whether a spot is a binary zero or one without altering the "switch" setting.
 35 That is accomplished by interrogating the spot with an infrared beam of low intensity in order to release a small fraction of the elevated energy electrons, enough to determine whether or not the spot is a binary one or binary zero. However, as a practical matter, not enough of the elevated energy electrons are released to significantly deplete the inventory of energized electrons stored at that spot. Utilizing the particular electron trapping thin film materials discussed herein for media storage, switching or write/erase speeds of 5
 40 nanoseconds or less are achieved.

As previously discussed, the present invention is directed to the use of multiple layers of differently doped electron trapping materials, one on top of the other on a disk or other substrate. Since each layer produces a different wavelength of output emission, it is possible to separate the read beam signals on that basis.

While the present three-dimension optical memory system is described using two differently doped media coatings, it is possible to use a plurality of different-doped media coatings. For example, at the present time, the assignee herein has developed at least four differently doped such mediums, which produce four different optical responses. The information to be stored and retrieved from a three-dimension optical memory system, whether it utilizes two or more media layers, can be written, read and erased by
 50 multi-color optical signals.

Since the media material used herein exhibits an extremely linear relationship between the intensity of the write input light and the light output for the media material triggered by a fixed-intensity read signal, data can be stored in analog form, as well as digital form.

In addition, the read, write and erase laser power requirements for the present invention are low. It is
 55 sufficient for the write energy to be a fraction of 1 picojoule per cubic micron, for example, about 0.5 picojoule per cubic micron. The read energy is at femtojoules, for example, about 10 femtojoules per cubic micron. The erase energy is about 1 picojoule per cubic micron.

Figure 6 is a side view of an optical disk showing the disk substrate 12 upon which the electron

trapping and optical layers are deposited. The disk substrate 12 is preferably made from an aluminum oxide material. However, it could also be made from other materials such as glasses, which can be readily coated with a thin film material and withstand the temperatures necessary to obtain a crystalline structure of the thin film materials. The first material deposited onto the disk substrate 12 can be an optional interlayer optical material 14 with a thickness of about several hundred Angstroms. The purpose of this interlayer 14 is to define a crystalline surface structure for the first electron trapping layer 16. It also provides a chemical barrier to prevent any leaching of the substrate material into the electron trapping layer 16. Any suitable material, such as CaO, MoO₃ or ZnS may be used, however ZnS is preferred. Any suitable deposition process may be utilized.

The second layer deposited on the disk 10, on top of the interlayer 14, is the first electron trapping layer 16. The thickness of the electron trapping material 16 is preferably about 5 microns. The deposition processes described in the pending United States patent applications referenced and incorporated herein may be used to deposit this layer onto the interlayer 14 already deposited onto the disk substrate 12.

A third or protective layer 18 may be optimally sputtered, evaporated, electron beam deposited or laid down on top of the first electron trapping layer 16 by any other known deposition method, such as chemical vapor deposition, etc. The protective layer 18 serves to chemically protect the electron trapping layer 16 from chemical contamination by chemically sealing the electron trapping layer 16. The protective layer 18 also serves to provide an optically clear coating over the electron trapping layer 16. It may preferably be comprised of aluminum oxide or some other suitable material.

The next layer deposited on the protective layer 18 is another interlayer 20. The use of interlayer 20 is optional. Where used, it serves the same functions as the first interlayer 14. A second electron trapping layer 22 is generated by physical vapor deposition on top of the interlayer 20 (or protective layer 18, if no interlayer 20 is present). It is doped differently than the first electron trapping layer 16 and so produces, upon being read, visible light of a different wavelength. A protective layer 24, having the same characteristics as the protective layer 18, is laid down on top of the second electron trapping layer 22.

A coating layer 26 of plastic or some other optically clear sealing material may optionally be used to coat the second protective layer 24. This coating layer 26 functions as do similar coatings on audio compact discs, as a barrier to environmental contaminants.

An optical disk 10 configured as described above and as shown in Figure 6 can be formatted by means of a laser which burns through the layers over the electron trapping layer 22 and permanently damages the second electron trapping layer 22 in a pattern indicative of the required formatting and track indicating information. Formatting and track indicating information schemes, such as those used with conventional Winchester disk drives or WORMs, can be utilized in this fashion to serve the same function with the instant optical disk drive system. Since the first electron trapping layer 16 always has a known relationship to the second electron trapping layer 22, it is not necessary to separately format that layer.

The method of damaging the electron trapping layer 22 functions as follows. The electron trapping material disclosed for use herein produces an instantaneous light when exposed to a visible light write laser beam, in addition to causing the storage of electrons in the trapping level T. That instantaneous emission, when exposed to the writing laser beam, can be used to elicit the stored tracking and formatting information by turning on the write laser beam when over the formatting and tracking portions of the disk. The bit areas damaged by writing at a much higher than normal wattage, such as 5 milliwatts using a read/erase laser beam, when struck by the write laser beam will not store an electron, and will not give off an instantaneous light.

Since a binary pattern of ones and zeros can be configured by using a strong laser as described above, the damaged areas which do not give off light correspond to binary zeros. The undamaged bits of the format and tracking information portions of the disk will give off light which represents a binary one. In that manner, the format and tracking schemes used with Winchester disk drives or WORMs can be utilized by the present optical disk drive system. Also, other known methods, such as using tracking information contained on the substrate disk itself. In a like manner to Winchester hard disk drives, an index signal can be provided by means of Hall effect devices contained in the spindle motor which rotates the optical disk. Two such devices are usually provided for redundancy purposes. Other known schemes for producing an index signal can also be utilized.

Referring now to Figure 7, there is shown therein a generalized schematic block diagram of the electronics and optics used for reading and writing data to and from the disk and transmitting that data to a host computer. The data from the host computer (not shown) is fed through a computer interface 20, which may, for example, be a standard ST506 interface as commonly used with Winchester disk drives and WORMs, or may be any other suitable interface. Data is output from the computer interface to the digital input electronics 22 of the drive. The digital input electronics, under microprocessor control from the power

and control circuitry 24, serve to format the data received from the computer interface 20 into a form appropriate to be used by the write electronics 26 to control the operation of the write lasers 28a and 28b.

One of the functions of the digital input electronics 22 is to convert the data received from the computer interface 20 into serial form so that it can be used by the write electronics 26 to modulate or turn on and off the write lasers 28a and 28b. Since two differently doped electron trapping materials are utilized in the illustrated example of the present inventions, two different wavelength write lasers 28a and 28b are required. For example, the two electron trapping media layers 26 and 22 are sensitive to different wavelengths of visible light. Under irradiation by an infrared read laser 38, each will emit a light signal of a different wavelength. Two such media materials are disclosed in co-pending commonly assigned United States Patent Application Serial Nos. 034,333 and 034,497 (Blue) and 034,332 (orange), all filed on April 3, 1987, and incorporated by reference herein. Media which emits a red wavelength of light is disclosed in United States Patent Application Serial No. 147,215, filed January 22, 1988 and commonly assigned herewith. That application is also incorporated by reference herein.

In the case of a two media layer system, the layers may emit, for example, orange light of approximately 620 nm wavelength and blue light of approximately 495 nm wavelength, respectively. Those media materials are sensitive to write wavelengths shorter than their emission wavelengths. In the case of a three layer system, a layer emitting red light of approximately 650 nm wavelength may additionally be utilized.

The amplitude modulated beams of the write lasers 28a and 28b are processed by the optical processing unit 30 which transmits the processed write beams to the head 32 which then focuses the beams onto the disk 10. The focus electronics 34 operate to produce a beam of each wavelength of about 1 micron in diameter for writing data to the disk. Alternatively, each write laser 28a and 28b can be operated individually so that only one media layer 16 or 22 is written to at a time.

The write laser could be a gaseous laser, such as an Argon laser. However, in order to construct the entire optical disk drive system including lasers, laser power supply and associated drive and laser control electronics circuitry in a package the size of a standard 5-1/4 inch drive of half or full height size, i.e., 5.75 in. wide x 8 in. deep x 1-5/8 in. in height or, 5.75 in. x 8 in. x 3.5 in., a solid state component must be used. Since no solid state lasers are presently available which produce a beam having a peak in the visible light range, the present invention utilizes two or more solid state frequency doubled diodes, such as the 840 nm diode laser with collimating optics and doubler available from Matsushita Corporation of Japan. The write electronics 26 are provided with at least two such diode lasers although of different output wavelengths. The digital input electronics 22 are the same as such electronics used in Winchester disk drives or WORMs.

In order to read the data written onto the disk as well as the format and tracking information contained on the disk, the microprocessor contained in the power and control unit 24 causes the laser electronics 36 to activate the read laser 38 to amplitude modulate or turn on and off its infrared beam which is transmitted to the hard mounted optical system 31. As described hereinbefore, it is preferred that the read laser have a wavelength peaking at approximately 1 micron or 1,000 nanometers. The hard mounted optical system 31 of the optical processing unit 30 transmits the processed read laser beam, by means of the head 32 and focus electronics 34, onto the surface of the disk 10 in order to cause the stored electrons written as binary ones (or as an analog signal) by the write lasers to leave the electron trapping layer T and to release photons. The photons are sensed by the head 32 which transmits them to the optical processing unit 30. The read laser 38 causes light emissions from each of the media layers, which can be separately sensed and processed since they are of different wavelengths. After processing by the hard mounted optical system 31, two light beams having peaks at a wavelength of about 650 nanometers and 495 nanometers, respectively, and transmitted to the detector assembly 40 and then to the detector electronics 42 where those beams are converted into electrical signals corresponding to the data pattern of sensed photons on each of the media layers 16 and 22 on the disk 10.

The output from the detector 42 is fed to the output electronics 44, which among other functions, converts the serial data stream from the disk into a parallel data stream for output back through the computer interface 20 to the host computer. Such output electronics as those used in Winchester hard disks or WORMs can preferably be used as element 44. The detector assembly 40 also functions, using a feedback loop system, to provide a feedback signal to the focus electronics 34 which maintain the head focus for the read and write laser beams on the disk.

The read/focus laser may preferably be a 'GALA' laser diode, model no. 1-9107 available from D.O. Industries. It produces an infrared laser beam having a peak at 830 nm. Alternatively, the read/focus laser 38, associated laser electronics 36, detector assembly 40, detector electronics 42, focus electronics 34 as well as much of the hard mounted optical system 31, as will be described in greater detail later, can be a Pencom Holographic optical Head, model no. 02 and pencom laser drive and focus actuation electronics

model no. 1800, available from Pencom International Corporation. The head 32 can preferably be an achromatic autofocusing objective, similar to the monochromatic Olypus 'TAOHS' autofocusing objective Model No. p37, available from Olympus Corporation of Japan.

The power and control section 24 of the drive also serves to maintain the optical disk at a constant rate of rotation in a known manner utilized by Winchester disk and WORM drive systems. It is preferred that the optical disk be rotated at a rate of at least 4000 rpm. Because the optical disk drive system of the present invention does not utilize a head which rests upon the surface of the disk when the disk is not rotating, there is no necessity to secure the disk from rotation when the drive is powered off. The power and control electronics 34 do, however, rotate the disk at a uniform speed and with a minimum of wobble as is commonly done by magnetic Winchester hard disk drives and WORMs. Both of those functions can be accomplished in any known manner.

Referring now to Figure 8, there is shown therein a cutaway pictorial drawing of the optical disk drive system which can be used with the present invention. The drive includes a spindle motor 11 which drives spindle 50 to which at least one disk 10 is rigidly mounted. The disk 10 is shown proportionately smaller than it actually is for purposes of clarity. As discussed herein, the disk drive system of the present invention has dimensions such that it fits within a standard slot of a personal computer for receiving a 5-1/4" Winchester disk drive, floppy drive, or WORM. The optical disk itself is preferably of diameter of about 130 millimeters with an inside diameter of 40 millimeters, that is, the same general size as a standard magnetic 5-1/4" hard disk. The drive also includes an actuator drive motor 52 which is shown as a linear actuator, for positioning the head 54 over the disk 10. Although the actuator drive motor is shown as a linear actuator, as is known in the art, a rotary type motor with a rotary positioning mechanism can alternatively be used.

The optical disk drive system of the present invention has the following specifications:

DRIVE SPECIFICATIONS	
Disk	
Track number/side	19,700
Track pitch	1.6 micron
Recording material	ETOMTM (2 layers)
Data transfer rate	200 Mbits/sec.
Storage Capacity	1.1 Gigabytes
Drive	
Rotation method	CAV
Disk rotation speed	>4000 rpm
Write laser power	0.1 mW
Write laser wavelengths	450 nm, 488 nm
Read laser power	0.5 mW
Read laser wavelength	830 nm
Erase Power	2.0 mW
Mass of moving carriage	<10 g
System	
Disk diameter	130 mm
Data transfer rate	>40 Mbits/sec.
Average access time	20 ms
C/N ratio (bandwidth 30kHz)	57dB
Error rate (without ECC)	10^{-6}
Error rate (with ECC)	10^{-12}
Direct read after write	Yes
Write verification	Yes

As described briefly in connection with Figure 7, the disk drive of the present invention also utilizes an optical processing unit 30, which will be described in more detail in connection with Figure 10. An electronics card cage 80 for supporting electronic circuit boards in a plane parallel to the optical processing unit may also be included in the construction of the optical drive system of the present invention. It should

be noted that in order to operate properly, the entire disk drive system should be enclosed in such a manner that outside light and contaminating particles cannot reach the surface of the disk. That practice is commonly used in connection with Winchester disk drives, as is a particle filtration system which can also preferably be used with the drive of the present invention.

5 It should also be noted that although Figure 8 shows an embodiment of an optical disk drive of the present invention with a single optical disk, such optical disk drive could be configured with an additional head in order to utilize the bottom surface of the disk 10, once it had been appropriately prepared in a manner as described hereinabove. Also, Figure 8 shows an optical processing unit 30 suitable for a single media layer. The optical processing circuitry suitable for a two media layer disk is shown in more detail in
10 Figure 10. In a like manner, a plurality of heads and disks can be utilized in order to increase the storage capacity of the optical disk drive system. The disk 10 could also be coated with additional electron trapping layers (more than two) to increase its storage capacity.

The erasable optical disk drive system of the present invention preferably uses a tracking system similar to or the same as is currently known and used with WORM drives. An alternative servo tracking
15 system, designed specifically to operate a rotary actuator mechanism for use with the present invention, is shown in Figures 9A and 9B. The circuitry of Figure 9A is a position tracking servo system which provides track following functions. The Figure 9B circuitry provides the velocity feedback signals for track seeking operations.

Referring now to Figure 9A, there is shown a schematic block diagram of the position tracking servo
20 system for use with a rotary actuator coarse positioning mechanism together with a galvanometer-based fine tracking mechanism. The rotary actuator mechanism, as is known in the disk drive art, works mainly in a lower frequency range below its resonances while the galvanometer operates at a higher frequency range. The rotary actuator/galvanometer system functions as if it were a resonance-free actuator because the crossover frequency between the two subsystems is high enough to neglect the movement of the
25 galvanometer which is mechanically separated from the rotary arm actuator.

The output from the detector D_1 of Figure 10 is fed into a phase compensator 90 of Figure 9A. The output from the phase compensator 90 is fed to the inputs of both low-pass and high-pass filters 92 and 94 respectively. The output of the low-pass filter 92 is used to drive the actuator 54a while the high-pass filter 94 output is fed to the galvanometer 96. In a known manner, a tracking error signal is generated by the
30 operation of the actuator 54a and galvanometer 96, which is fed back ultimately to the phase compensator 90. In this manner, the feedback loop of Figure 9A reduces the off-track errors for the rotary actuator 54a to the range of tenths of a micron. The galvanometer 96 reduces that error to a range of hundredths of a micron. Since the angular range of the galvanometer is in the order of seconds, any tracking offset caused by beam deflection is negligible.

Figure 9B is a schematic block diagram of the velocity tracking servo system for use with the present
35 invention. The track seeking operation is executed under a known velocity-profile system. A laser beam spot, starting from a track, lands on a target track after acceleration, constant velocity movement, and, finally, deceleration. During the deceleration phase, the velocity is controlled by referring to a distance-velocity table stored in the ROM 102, which is programmed such that the velocity of the actuator 54a
40 becomes almost zero at the target track. The distance between the starting point and the target track is measured by track-crossing signals and counted by track counter 100. The velocity in the high velocity range is obtained from the time duration of each signal. In the lower velocity range, the time duration is obtained from the differential of the signal at each zero-crossing point.

The output from the track counter 100 is inputted to the ROM 102 whose digital output is converted to a
45 corresponding analog signal by digital-to-analog converter 104 and fed to a differential amplifier 106 whose output is fed to both the low and high pass filters, 92 and 94. The outputs of those filters are used to drive the actuator 54a and galvanometer 96. The differential 106 is also connected to receive a signal indicating whether the actuator is to be driven in either high velocity or low velocity mode.

Figure 10 is a block diagram of a preferred embodiment of the optical processing unit 30 suitable for a
50 disk 10 having two electron trapping media layers 16 and 22. Also shown is the actuator assembly 54. The modulated beam of the first write laser 28a is reflected from a first broad band mirror M_1 to a second broad band mirror M_2 and then passes through two lenses L_1 and L_2 until it reaches an element of a polarizing beam splitter PBS_2 which preferably provides as an output a laser beam with peaks at a wavelength of about 450 nanometers. PBS_2 is preferably a 488 nm polarizing beam splitter cube, model no. 03PBS 013,
55 available from Melles Griot Corporation. Lens L_1 is preferably a 50 millimeter precision optimized achromatic doublet lens while lens L_2 is preferably a 200 millimeter precision optimized achromatic doublet lens, both available from Melles Griot Corporation.

After being reflected by the polarizing beam splitter PBS_2 , the write laser beam passes through mirror

M_8 , which is an 850 nm reflector, and then through mirror M_9 , which is preferably a 650 nanometer wavelength reflector mirror, and onto lens L_6 which is an Olympus 'TAOHS' autofocusing objective as discussed above. The 450 nm write beam is then reflected by broad band mirror M_7 and translated 90° to impinge onto the surface of the optical disk 10. The lens L_6 and broad band mirror M_7 are contained on the actuator assembly 54 which includes an actuator arm assembly and head.

As previously discussed, both write laser beams 28, which have different wavelengths to which the two media layers 16 and 22, respectively, are sensitive, may operate either singly or simultaneously. Obviously, only the media layer which is sensitive to the particular write beam wavelength operating has data written to it.

The 650 nm reflector M_9 may preferably be a 6328 dielectric reflector, model no. 02 MFG007/279, available from Melles Griot Corporation. It functions to reflect only wavelengths which peak around 620 nm, such as the orange light or data given off by the first electron trapping layer 16 of the disk 10 in response to the read laser beam. The mirror M_7 , which reflects the incident write and read laser beams to focus on the lens L_6 into a path 90° away from the incoming beams, is preferably a broad band reflector, model no. 10D10BD-1, available from Newport Corporation. Mirrors M_1 and M_2 may preferably also be the same mirror as mirror M_7 . Mirror M_7 also functions to reflect into a path 90° away from the incoming path the data stored on the disk in its orange light form and focused onto the mirror M_7 by the lens L_6 . Such "light beam" is really a stream of orange light or "bits" read from the disk 10. The actuator arm assembly may be of any known construction. Suitable such assemblies are utilized in well known WORM drives.

The modulated beam of the second write laser 28b provides an output laser beam having its peak centered at a wavelength of about 495 nanometers. The modulator beam from that second write laser 28b strikes the polarizing beam splitter PBS2 at an angle 90° away from the incident write laser 28a beam and thus passes through the polarizing beam splitter PBS2 and through mirrors M_8 and M_9 and onto lens L_6 . The 495 nanometers second write beam is then reflected by broad band mirror M_7 and translated 90° to impinge onto the surface of the optical disk 10. As previously described, in the same manner as with the orange light associated with the first electron trapping media layer 16, the blue light associated with the second electron trapping layer 22 and write laser 28b is reflected off of the disk and focused onto the mirror M_7 by the lens L_6 . Again, such a "light beam" is really a stream of blue light or "bits" read from the second media layer 22 of the disk 10.

The read/focus laser 38, which preferably has its peak wavelength in the infrared range centered around a wavelength of 800-1100 nanometers, is first reflected 90° by a broad band mirror M_4 and then another 90° by a second broad band mirror M_5 which directs the read/focus laser beam to the back of a polarized beam splitter PBS₁ having a wavelength centered about 830 nanometers. The read/focus beam, which is polarized in a plane parallel to the surface of the drawing, passes through the polarized beam splitter PBS₁ and through a quarter wave plate λ_4 , which may preferably be a model no. 02URQ001 available from Melles Griot Corporation. The quarter wave plate changes the polarization of the read beam to circular polarization. The read beam then impinges on an 850 nm reflector mirror M_8 , which bends the beam 90° to impinge on the 650 nm dielectric reflector mirror M_9 . The read/focus beam passes through the mirror M_9 in the same manner as the write laser beams and impinges onto the lens and mirror combination L_6 and M_7 of the head 32 secured to the actuator assembly 54 which focuses it onto the surface of the disk 10.

A portion of the read/focus beam is reflected off of the surface of the disk 10, through the objective formed by lens L_6 and mirror M_7 and through mirror M_9 to mirror M_8 . Due to its reflection off of the disk 10 surface, the polarization of the focus beam is now in the opposite circular direction to the circular polarization of the read/focus beam. The focus beam is reflected 90° by the mirror M_8 and through the quarter wave plate λ_4 , which changes its polarization to vertical or perpendicular to the surface of the drawing. It then impinges onto the front of the polarized beam splitter PBS₁, which may preferably be a 830 nm polarized beam splitter tube, model no. U3 PBS063, available from Melles Griot Corporation. The beam splitter PBS₁ reflects the focus beam at an angle 90° to the incident beam which causes the focus beam to impinge on mirror M_5 , which may preferably be a diode laser reflector, model no. 10 DIOBD-2, available from Newport Corporation. Mirrors M_3 and M_4 may preferably be that same part.

The mirror M_5 reflects the focus beam at an additional 90° angle such that it is on a path parallel to, but travelling in opposite direction to, the output laser beam from the read/focus laser 38. The focus beam is reflected by mirror M_5 onto and focused through a first lens L_3 , which may preferably be a 75 millimeter precision optimized achromatic doublet lens and then through a second lens L_4 which may preferably be a 50 millimeter plano convex cylinder lens model no. 850-50, available from Optics Plus, Inc., and onto a focus/tracking detector D_1 . Such detector D_1 forms a part of element 40 in Figure 7 and may preferably be a quadrant detector, model PIN-SPOT-4DMI, available from United Detector Technology Corporation. The output from detector D_1 is utilized by the detector assembly 40 to produce a feedback signal for use by the

focus electronics 34 for maintaining the focus of the read and write laser beams by the head 32, as well as providing an input to the detector electronics 42. The hard mounted optical system 31 is formed of the optical elements shown in Figure 10, excluding elements 28, 38, D₁, D₂, D₃ and the actuator assembly 54 in its entirety.

5 The different "sets" of photons released by the impingement of the read beam onto the surface of the disk 10 pass through the lens L₆ and are bent by the mirror M₇ and caused to impinge on the backside of the reflector M₉. The reflector M₉ translates the two outgoing data beams 90° away from the input write beams and directs them through a lens L₅, which may preferably be a 120 millimeter focal length precision optimized achromatic doublet lens available from Melles Griot Corporation. From the lens L₅, the data
10 beams impinge on a dichroic or two color mirror M₆ which translates the orange beam 90° to pass through an optional 620 nm interference filter f₁ to impinge onto a data read detector D₂. The data read detector D₂ forms a part of the detector assembly 40 described in connection with Figure 7. The dichroic mirror M₆ may preferably be a Model No. 07D10 DM.4, available from Newport Corporation.

The blue data beam impinging onto the cold half-silvered mirror M₆ passes therethrough to impinge on
15 an optional 450 nanometer interference filter f₂ to impinge onto a second data read detector D₃. The second data read detector D₃ forms a part of the detector assembly 40 described in connection with Figure 7. In that manner, the separate orange and blue "data streams" can be separated and separately processed such that two separate data streams, output from the first and second data read detectors D₁ and D₂, will be produced. Such data streams may be separately processed and provided as parallel outputs from the
20 detector 40. Those data streams may be output either separately to a plurality of computer interfaces 20 or in combination to a single computer interface 20.

Although only a preferred embodiment is specifically illustrated and described herein, it will be appreciated that many modifications and variations of the present invention are possible in light of the above teachings and within the purview of the appended claims without departing from the spirit and
25 intended scope of the invention.

Claims

- 30 1. A computer optical disk drive system, comprising:
an optical disk comprising at least two layers of different electron trapping media for storing digital information in the form of light energy, said optical disk being fixedly mounted in a sealed housing;
means for rotatably supporting said optical disk;
means for rotating said optical disk;
- 35 transducer means comprising at least three light beam generating means and a focusing objective for writing information on and reading information from said optical disk as light energy on at least one planar surface thereof; and
positioning means for moving said focusing objective between the tracks on said optical disk, said
40 positioning means including means for moving said focusing objective from one track to the next adjacent track on said optical disk.
2. A computer disk drive system for operating an erasable optical disk drive, said optical disk drive system comprising:
at least one optical disk fixedly mounted in a sealed housing, said optical disk comprising at least two
45 layers of different characteristic media for storing and releasing information in the form of light energy;
means for rotatably supporting said optical disk;
means for rotating said optical disk;
transducer means comprising at least three light beam generating means and a focusing objective for
50 writing information on and reading information from said optical disk as light energy on at least one planar surface thereof; and
positioning means for moving said focusing objective between the tracks on said optical disk, said
positioning means including means for moving said focusing objective from one track to the next adjacent
track on said optical disk.
3. The computer optical disk drive system of Claim 1, wherein said sealed housing contains at least said optical disk, said transducer means, and said positioning means.
- 55 4. The computer optical disk drive system of Claim 3, wherein said housing is of dimensions 5.75 inches in width, 8 inches in depth, and 3.5 inches in height.
5. The computer optical disk drive system of Claim 1, wherein said at least three light beam generating means are contained on a single circuit card.

6. The computer optical disk drive system of Claim 1, wherein one of said at least three light beam generating means produces a beam having a wavelength in one of the near infrared and infrared light spectrum.

7. The computer optical disk drive system of Claim 1, wherein two of said at least three light beam generating means produce beams having different wavelengths in the visible light spectrum.

8. The computer optical disk drive system of Claim 1, wherein one of said at least three light beam generating means produces a beam having a wavelength in one of the near infrared and infrared light spectrum for reading information from said optical disk and the others of said at least three light beam generating means produce beams having different wavelengths in the visible light spectrum for writing information on said optical disk.

9. The computer optical disk drive system of Claim 1, wherein said electron trapping media coatings on said optical disk store information in the form of an increased energy level of electrons.

10. The computer optical disk drive system of Claim 1, wherein said electron trapping media coatings on said optical disk release stored information in the form of light energy of a wavelength having peaks centered about different predetermined wavelengths.

11. The computer optical disk drive system of Claim 1, wherein each of said light beam generating means used for writing digital information on said disk generates a light beam having a different predetermined wavelength and said light beam generating means used for reading digital information from said disk generates a light beam having yet another and different predetermined wavelength.

12. The computer optical disk drive system of Claim 11, wherein said optical disk, upon the impingement of said reading light beam, produces at least two light emissions of predetermined different wavelengths.

13. The computer optical disk drive system of Claim 1, wherein said digital information is written on and read from said optical disk by amplitude modulation of said at least three light beam generating means.

14. A method of operating an erasable optical disk drive for a computer, including the steps of:
coating the surface of an optical disk with at least two electron trapping media layers which store information in the form of light energy;
rotatably fixedly supporting said optical disk;
rotating said optical disk at a constant predetermined rate of rotation;
impinging focused light beams of at least three predetermined different wavelengths on said disk surface for writing information onto and reading information from said optical disk; and
positioning said impinging focused light beams from track to track and on said optical disk, such that desired information is written to and read from said optical disk.

15. The method of Claim 14, further including the step of impinging one of the at least three focused light beams of predetermined different wavelengths at a power substantially higher than used to read information on said optical disk, for erasing the information written on said optical disk.

16. The computer optical disk drive system of Claim 1, wherein said system has the capacity for storing at least 500 megabytes of information per disk side.

17. An optical disk for use with a computer optical disk drive system, comprising a substrate having at least two coatings of electron trapping materials each having a predetermined different spectral sensitivity characteristics for storing information in the form of light energy.

18. The optical disk for Claim 17, further including an interlayer lying directly on the surface of said substrate to form a layer upon which one of said electron trapping materials is placed.

19. The optical disk of Claim 18, further including a protective layer deposited on top of one of said electron trapping materials for preventing chemical contamination of said disk.

20. The optical disk of Claim 17, wherein said substrate is comprised of alumina.

21. The computer optical disk drive system of Claim 1, wherein said system has the capacity for storing at least 1 gigabyte of information per disk side.

22. An erasable optical disk drive system, comprising:
an optical disk comprising a substrate upon which at least two different layers of storage media each having a predetermined sensitivity to a different wavelength of visible light are coated for storing information in the form of light energy, said optical disk being fixedly mounted in a sealed housing;
means for rotatably supporting said optical disk;
means for rotating said optical disk;
transducer means for simultaneously writing information to said at least two different layers of storage media on said optical disk and for simultaneously reading stored information from said at least two different layers of storage media on said optical disk using means for focusing writing and reading light beams on at least one planar surface of said optical disk; and

positioning means for moving said means for focusing from one track to the next adjacent track on said optical disk.

23. The erasable optical disk drive system of Claim 22, wherein said transducer means simultaneously writes information to at least one layer of said storage media while reading stored information from at least one different layer of such storage media.

24. The erasable optical disk drive system of Claim 22, wherein each of said different layers of storage media emits a predetermined different wavelength of light upon being read.

25. The erasable optical disk drive system of Claim 24, further including means for separately detecting each of said predetermined different wavelengths of light and separately converting of each of the detected wavelengths of light to electrical signals.

26. The erasable optical disk drive system of Claim 26, wherein said detecting and converting of each of said predetermined different wavelengths of light occurs simultaneously.

27. The erasable optical disk drive system of Claim 25, wherein said detecting and converting of each of said predetermined different wavelengths of light occurs in a parallel manner.

28. An optical disk for use with the computer optical disk drive system as claimed in Claim 1 comprising a substrate having at least two coatings of electron trapping materials each having a predetermined different spectral sensitivity characteristics for storing information in the form of light energy.

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eingereicht / Newly filed
Nouvellement déposé

FIG. 1

CONDUCTION BAND
(almost empty)

COMMUNICATION BAND E

TRAPPING LEVEL T

VALENCE BAND G
(ground state, full)

charging light

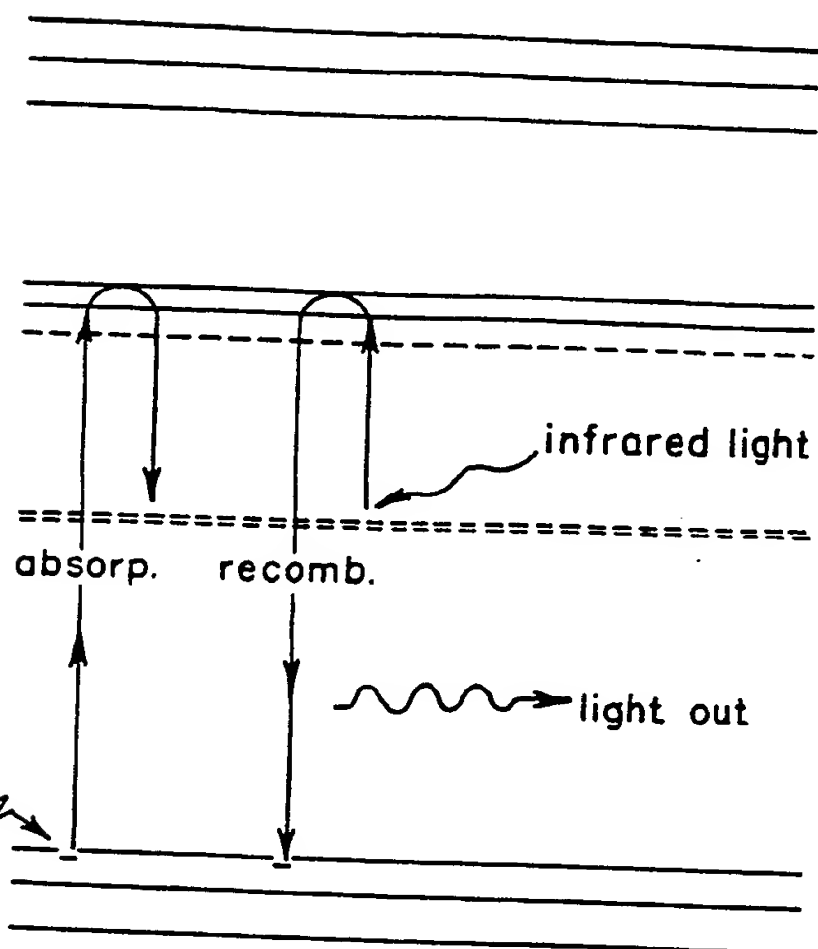


FIG. 6

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26	COATING LAYER (optional)
24	PROTECTIVE LAYER
22	SECOND ELECTRON TRAPPING LAYER
20	INTERLAYER
18	PROTECTIVE LAYER
16	FIRST ELECTRON TRAPPING LAYER
14	INTERLAYER
12	DISK SUBSTRATE

eingereicht / Newly filed
Nouvellement déposé

FIG. 2

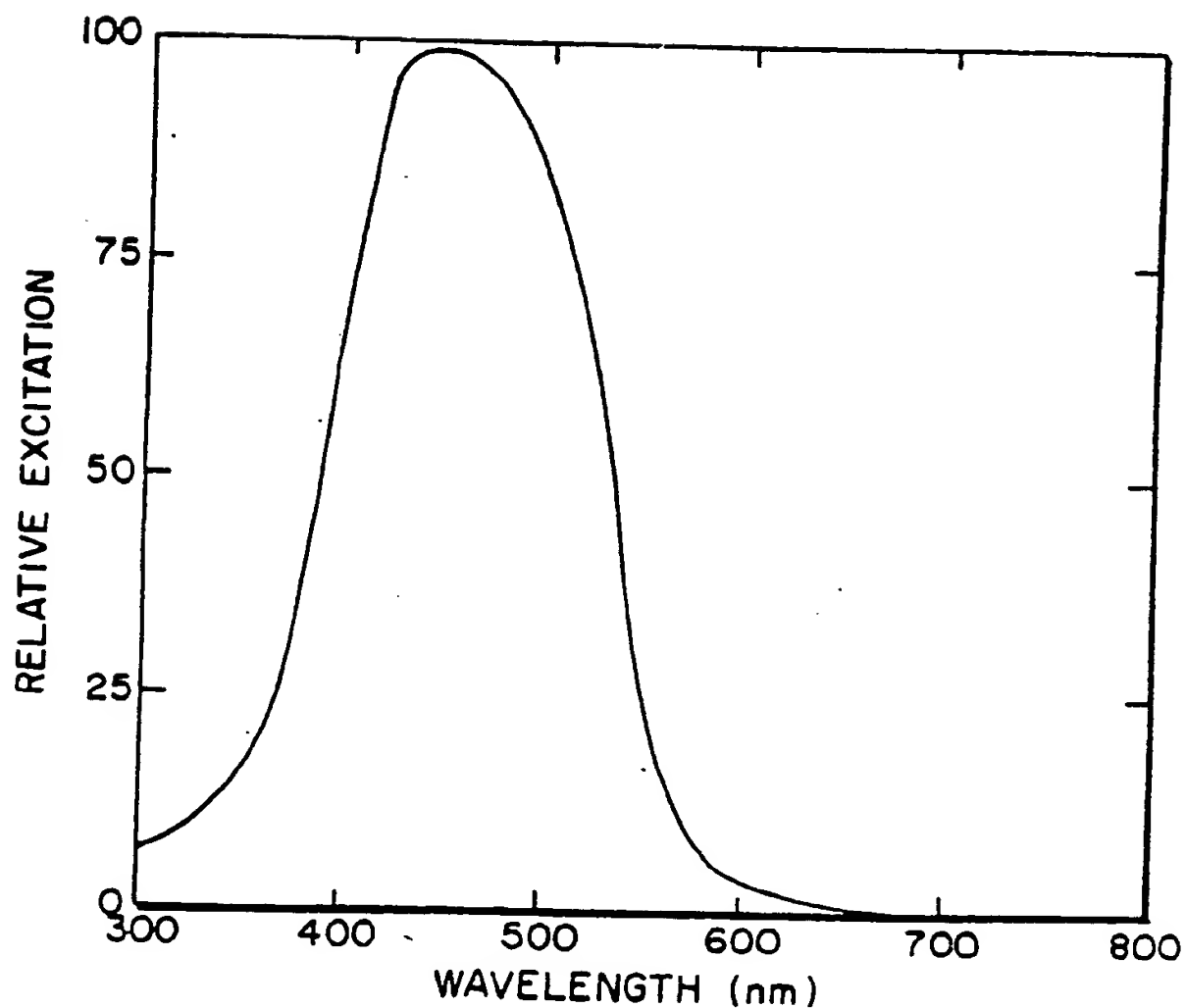
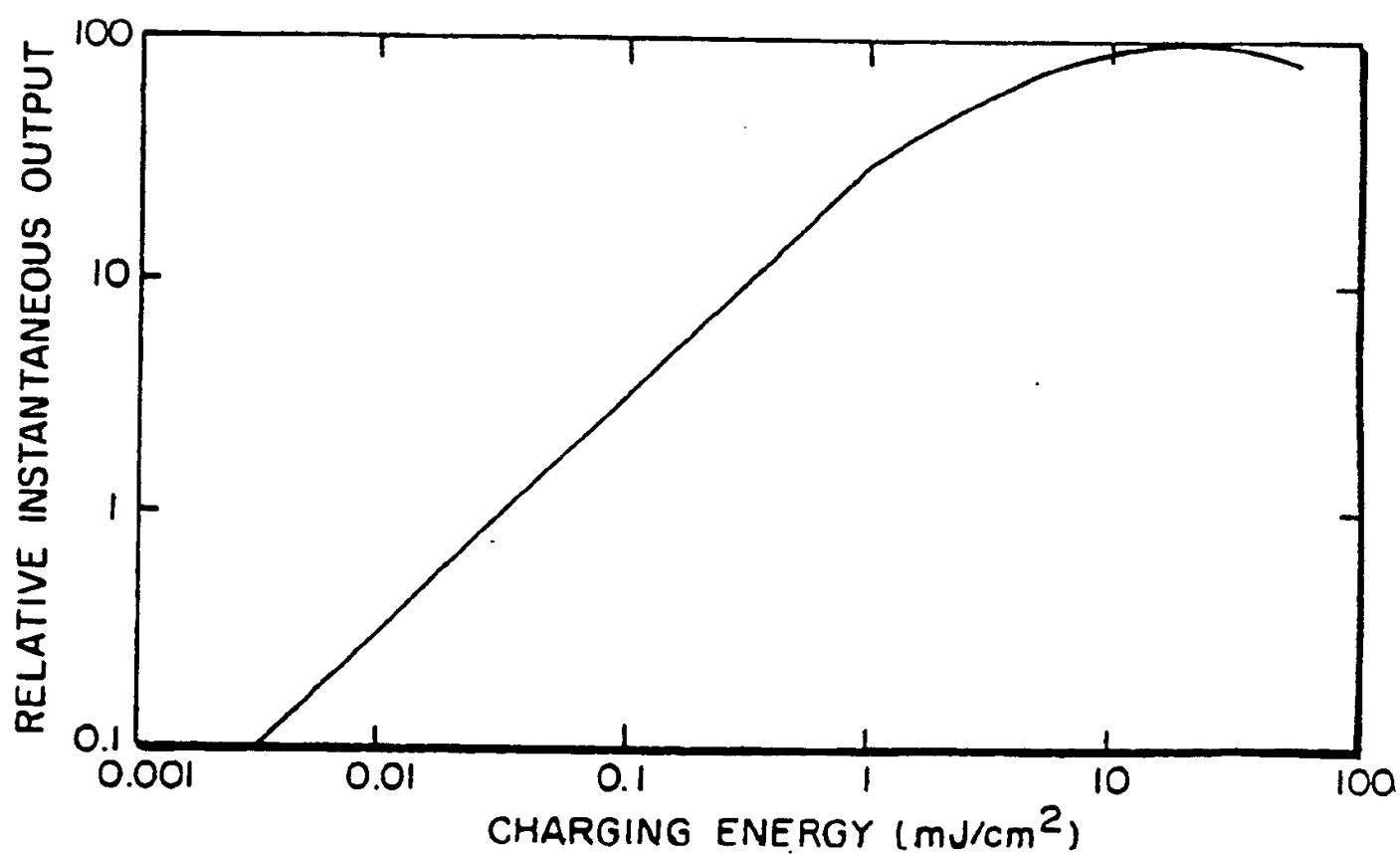


FIG. 5



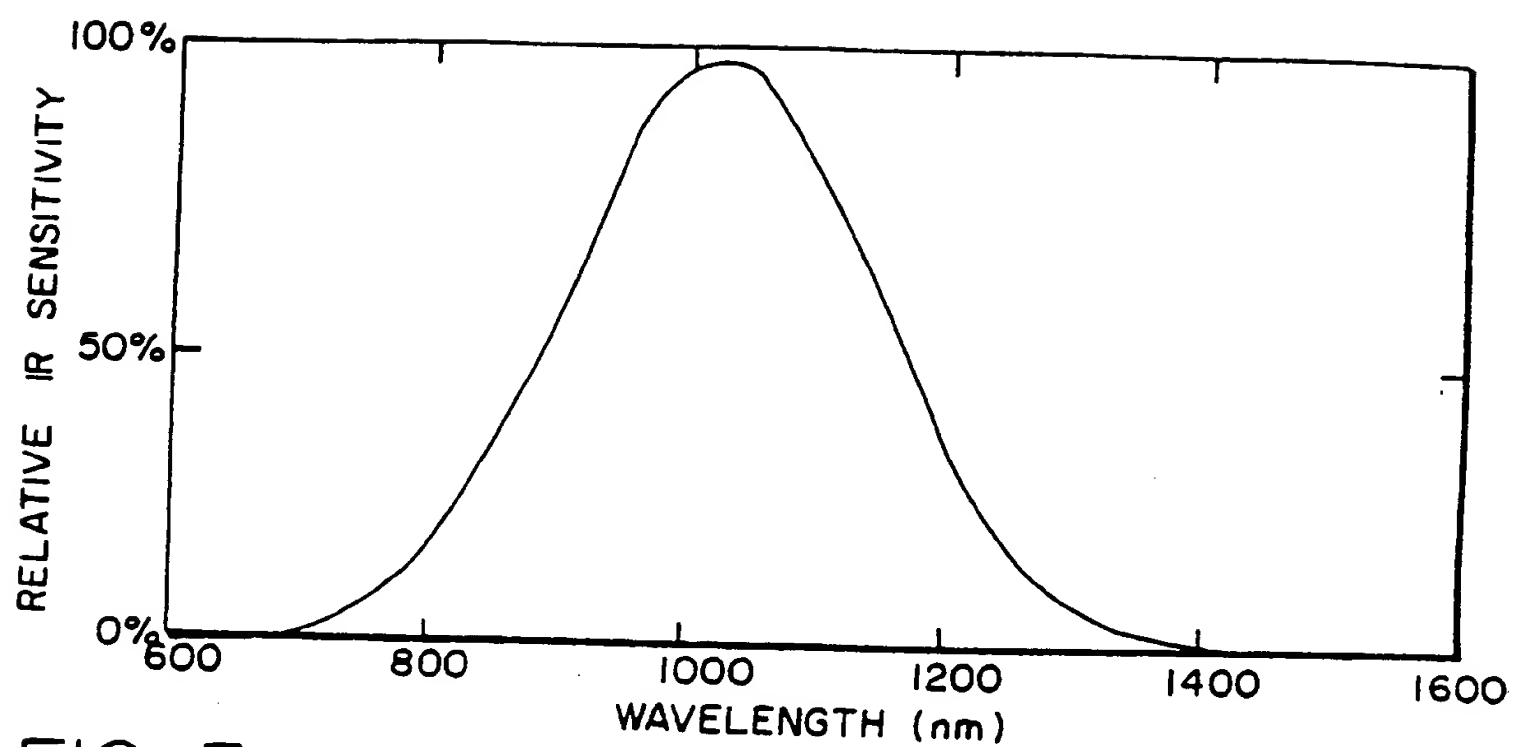


FIG. 3

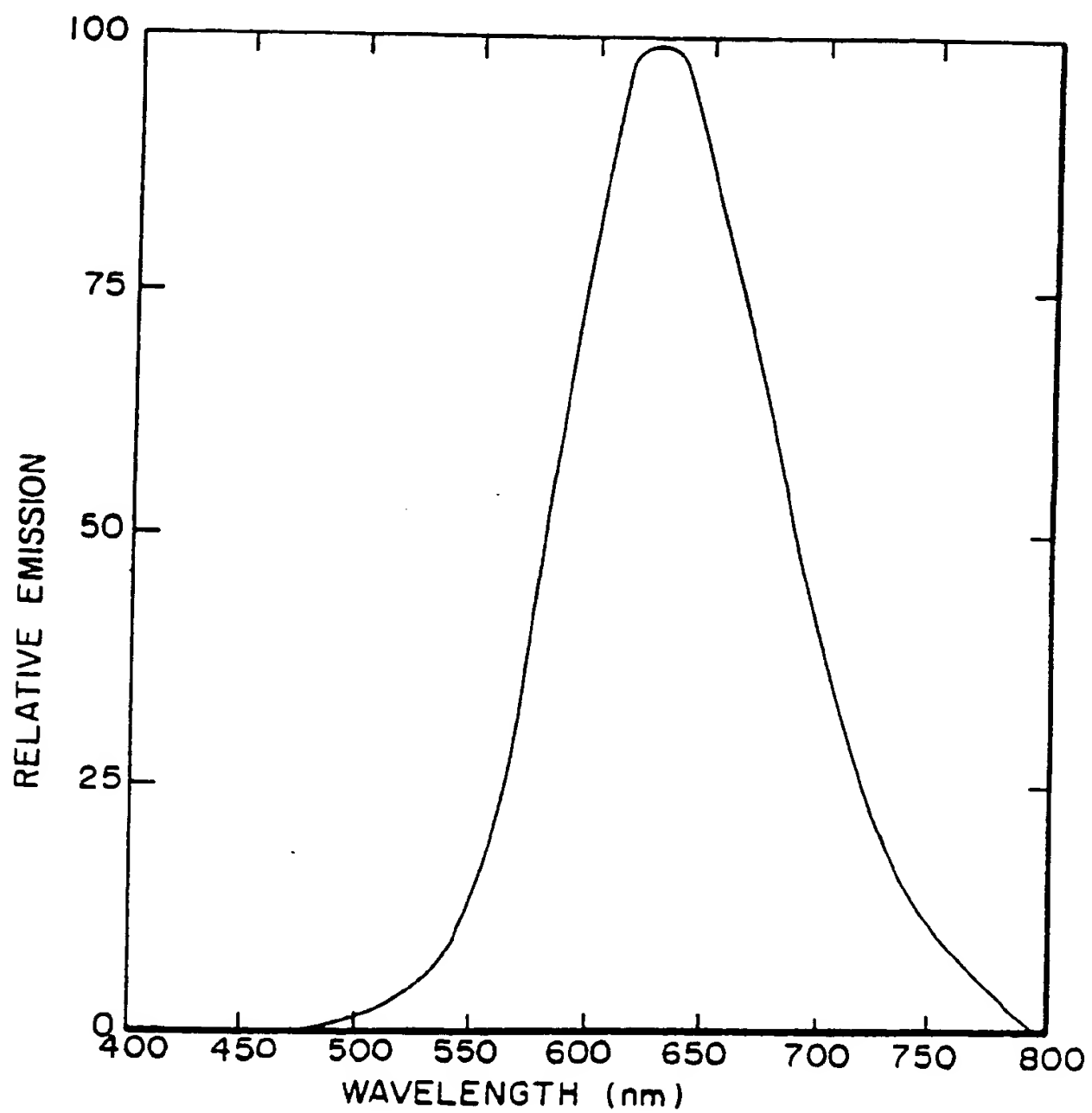


FIG 4

FIG. 7

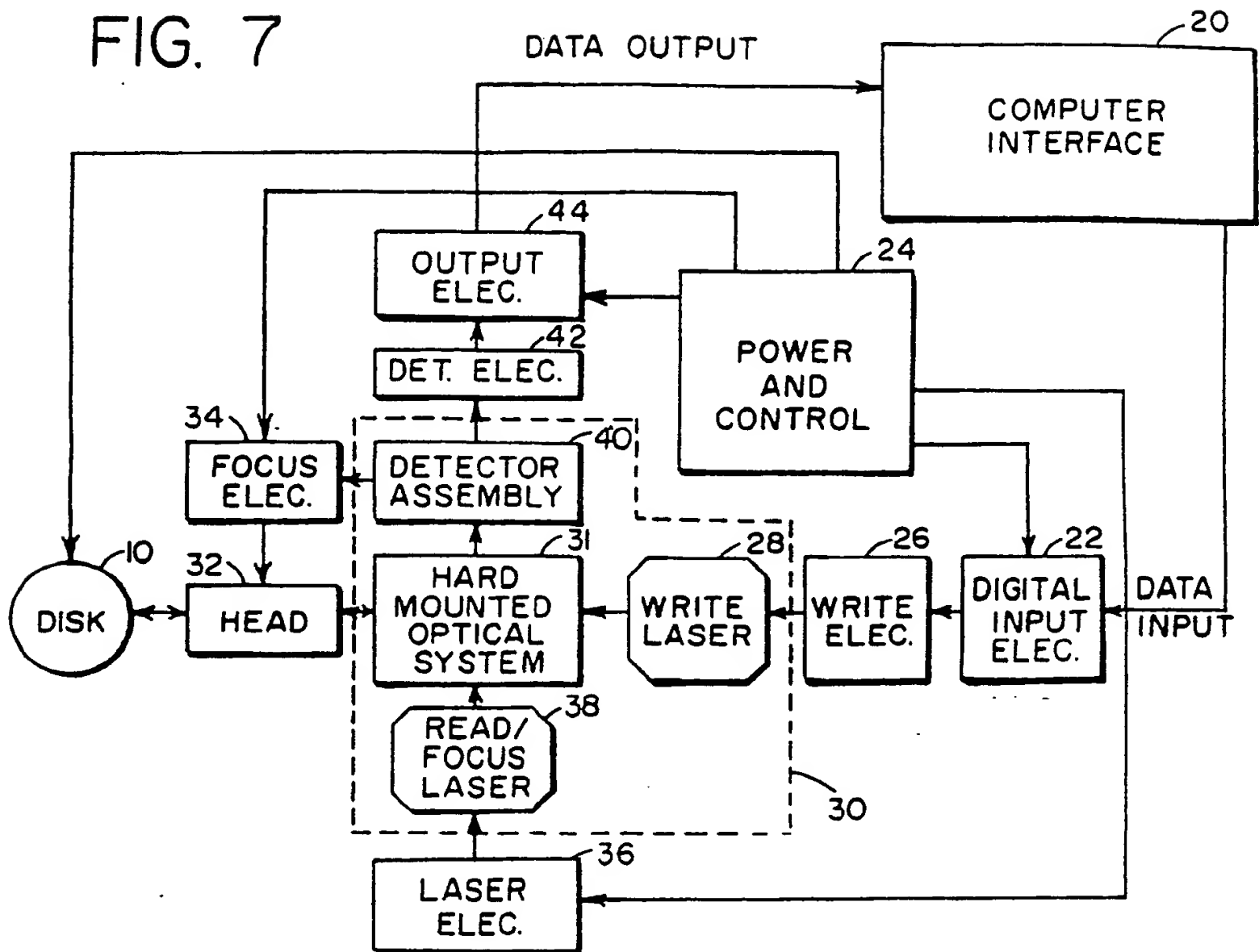
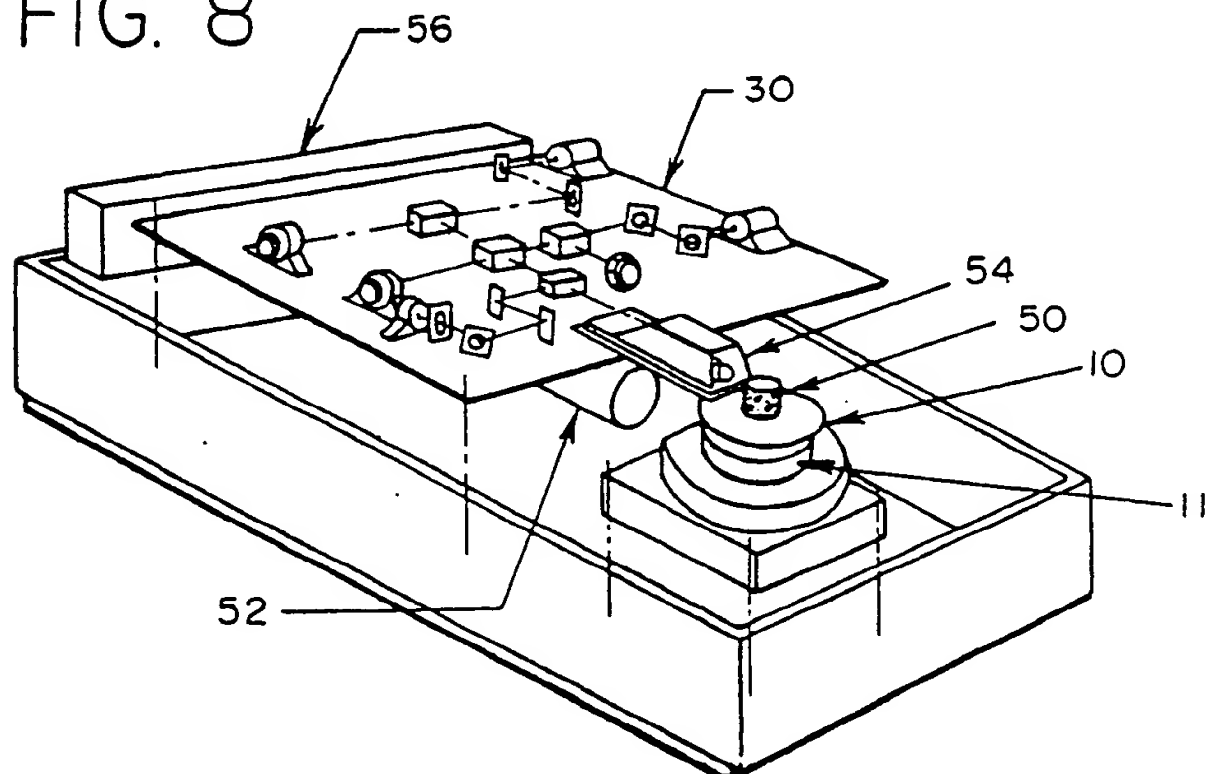


FIG. 8



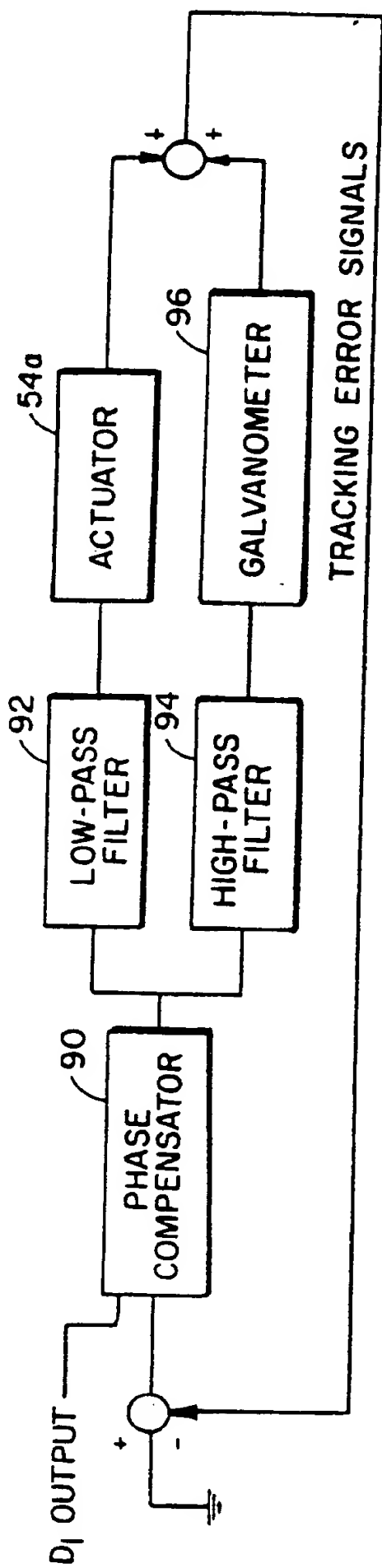


FIG. 9A

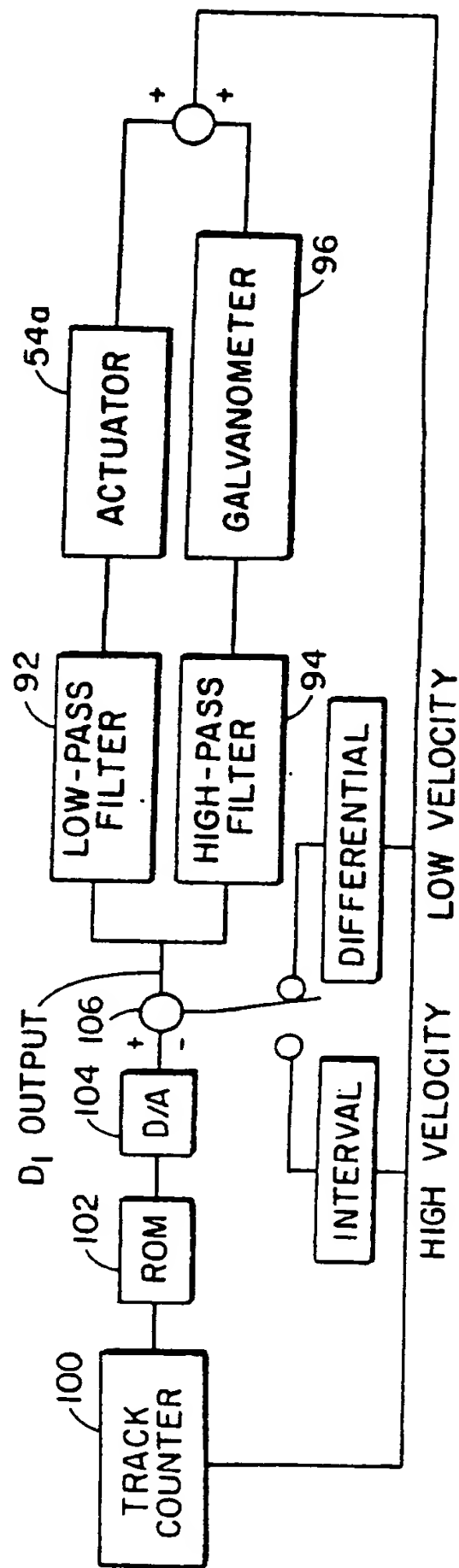
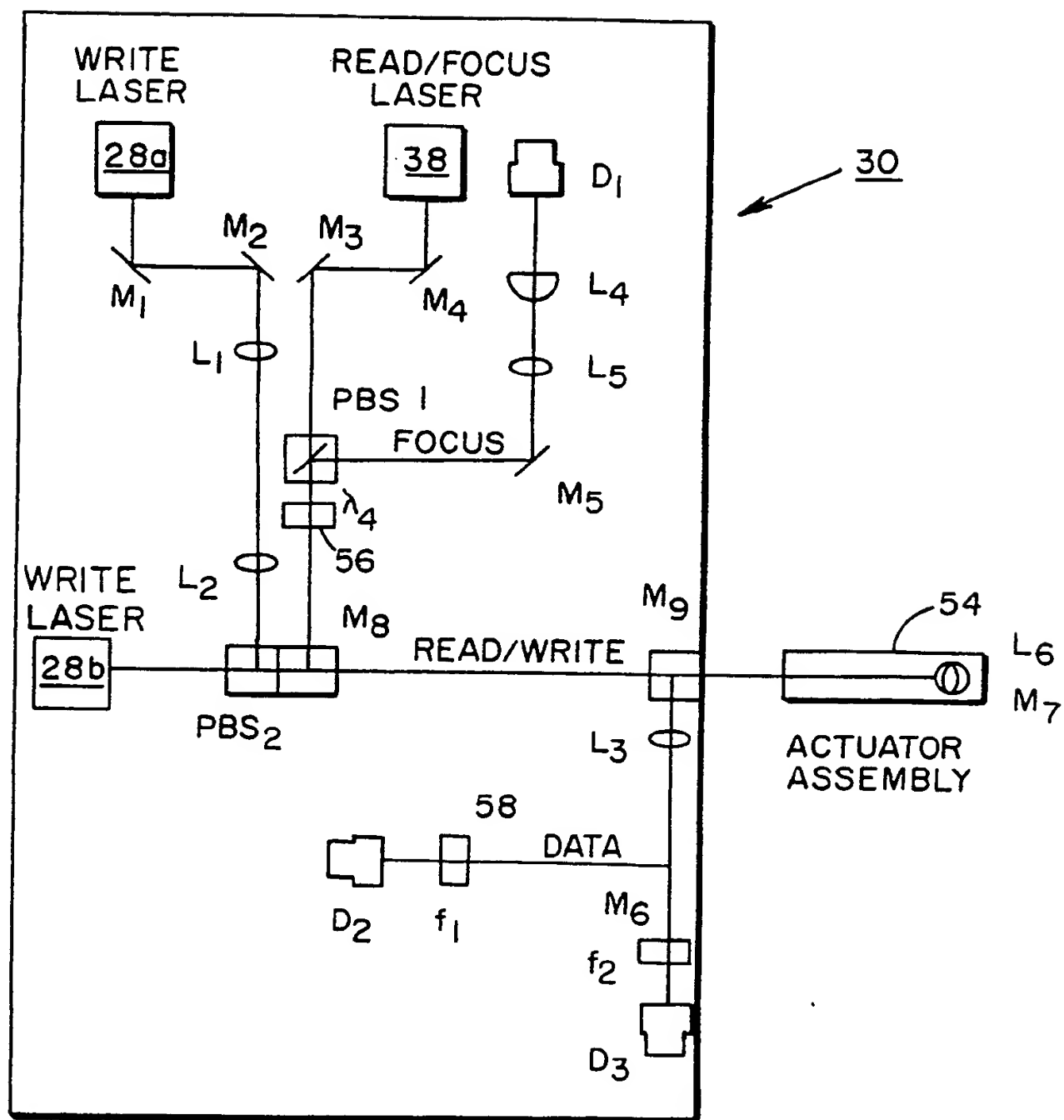


FIG. 9B

FIG. 10



(19)



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(54) **Three-dimensional optical memory system.**

(57) A three-dimensional optical memory system is disclosed which utilizes at least two layers of electron trapping media having different sensitivities to visible light coated on a substrate to store data in the form of light energy. Data is written onto the substrate, which may be in the form of a disk, which is contained in a light-tight contamination-free environment similar to a Winchester hard disk drive

system, using at least two visible light laser beams having different wavelengths. Data is read from the disk using an infrared light laser beam. The at least two different data streams are separately detected. The system may be used as part of an optical disk drive system which is designed to fit within a standard mini or 5-1/4 inch disk drive form factor for personal computers.

FIG. 1

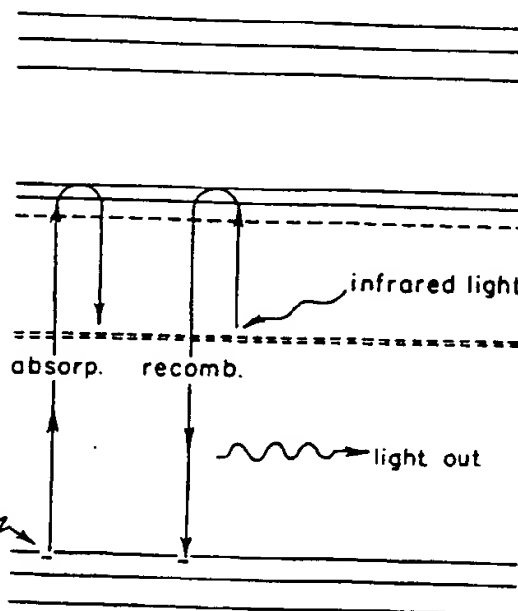
CONDUCTION BAND
(almost empty)

COMMUNICATION BAND E

TRAPPING LEVEL T

VALENCE BAND G
(ground state, full)

charging light

**EP 0 371 580 A3**



European
Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 89 30 7166

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	SOLID STATE TECHNOLOGY. vol. 31, no. 8, August 1988, WASHINGTON US pages 135 - 138; J. LINDMAYER: 'a new erasable optical memory'	17	G 11 B 7/00 G 11 B 9/00
Y	* the whole document *	1,2,14,22	
A	US-A-4 375 091 (W.R.DAKIN ET AL) * column 2, line 29 - column 3, line 65 * *	1,2,14,22	
P,Y	DE-A-3 827 738 (MITSUBISHI DENKI KABUSHIKI KAISHA) * column 1, line 60 - column 2, line 64 * * * column 5, line 2 - column 6, line 42; figure 3 * * * * column 8, line 30 - line 66; figure 5 * *	1,2,14,22	
			TECHNICAL FIELDS SEARCHED (Int. Cl.5)
			G 11 B
The present search report has been drawn up for all claims			
Place of search		Date of completion of search	Examiner
The Hague		03 February 92	SZUBERT J.M.G.
CATEGORY OF CITED DOCUMENTS			
X: particularly relevant if taken alone			
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